Road Dust resuspension and toxic components

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Air pollution and Health

Equipment

Two aerosol mobile units were placed at two traffic sites (Alcala and Maldonado) in Madrid (Spain). They were equipped with instruments for the continuous measurements of levels of NO, NO_2, NO_x, O_3 and CO. For the monitoring of particulate matter in each mobile unit were also installed:

•One MCV high volume sampler (30 $m^3 h^{-1}$) with DIGITEL PM_{10} inlet for the determination of PM_{10}. PM_{10} particles were collected on a 24h basis using quartz-fiber filters (15 cm diameter).

•One Light scattering particle counter (Grimm) using 30 minutes time intervals for the continuous monitoring of PM_{10}, and $PM_{2.5}$ mass concentrations.

For the collection of a satisfactory number of 24h samples intended for source apportionment, another traffic site that belongs to the local monitoring network was used, named Esc.Aguirre (Figure 1) where a MCV high volume sampler was also placed.

Figure 2. Mobile unit equipped with MCV sampler and Grimm optical counter

Methodology

During the one month campaign the followed procedure was: For one week the road surface was washed daily with high-pressure water systems to prevent suspension of road dust and the next week the road was left untreated to observe any potential increase in PM ambient concentrations and particle loading of the road surface. This was repeated for another two weeks period.

Road dust sampling was conducted in ALCALA site (Figure 2) where the road surface was untreated and at one reference site with daily street washing. Road dust samples were collected on quartz filters with the device (Figure 3) described in Amato et al., 2009.

The road dust sampling protocol included two samplings per day in the morning and evening hours when the traffic peaks. This procedure focused on examining the diurnal trends of road dust loadings and the source strength of resuspension.

Figure 3: a) PM10 resuspension sampler; b) Sampled filter

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Background

Several studies in Spanish urban areas have shown high concentrations of aerosol particles. These air pollution problems are in most cases attributed to traffic. Traffic emissions include exhaust origin particles, as well as particulate matter from abrasion sources like tire and brake wear debris and particles resuspended by the road surface. Street washing is one of the methods that might reduce the occurrence of dust re-entrainment by reducing the amount of dust on the road. In recent years, street washing and sweeping are being used by local authorities, mainly for aesthetic reasons. The environmental protection authorities promote street cleaning work, but the effect of this method in the urban air quality is not yet clear.

Previous studies in the urban area of Madrid (central Spain) point out traffic as the main source of fine particles and dust resuspension was identified to be responsible for the elevated levels of coarse particles (Artiñano et al., 2004; Querol et al, 2004; Salvador et al., 2004). Since 2007 the local authorities implement street washing in a major part of the urban region of Madrid. However, an exhaustive study in order to examine the effect of this method to the air quality has not yet being conducted.

The aim of this study was to quantify the contribution of road dust to particulate matter, and evaluate the effects of street washing on the strength of resuspension.

Study Area

An intensive sampling campaign was conducted during summer 2009 in central Madrid. Aerosol monitoring included air quality measurements at two traffic sites, ALCALA and MALDONADO along one busy street placed 1.5 km apart and at one fixed site, named ESCUELAS AGUIRRE monitored by the Madrid City Hall authorities, Figure 1.

Figure 1. Madrid urban area with the sampling sites marked. The arrow indicates the direction of the traffic flow

PM_{10} gravimetric mass concentrations

Table 1. Average daily concentrations for the StW days and for no StW days for the three sampling sites

PM_{10}, $\mu g\ m^{-3}$ ± sd	MALDONADO	ALCALA	ESCUELAS AGUIRRE
All samples	36.5 ± 8.8	45.0 ± 11.0	40.3 ± 9.1
StW	35.7 ± 10.9	42.6 ± 8.4	38.8 ± 11.2
no StW	37.2 ± 6.3	46.8 ± 12.5	41.3 ± 7.8

Table 1 provides the average PM_{10} concentration values and the standard deviation calculated for the sampling sites, Alcala, Maldonado and Escuelas Aguirre. The data were divided in two different subsets: days with street washing, (StW) and days without street washing, (no StW).

Concerning the variation in PM_{10} ambient levels between these subsets a difference of ~4 $\mu g\ m^{-3}$ (~10% of the average mass concentration) was observed in Alcala. In Maldonado and Esc.Aguirre sites the difference was smaller, around 2 $\mu g\ m^{-3}$(~4% of the average mass concentration).

PM continuous mass concentrations

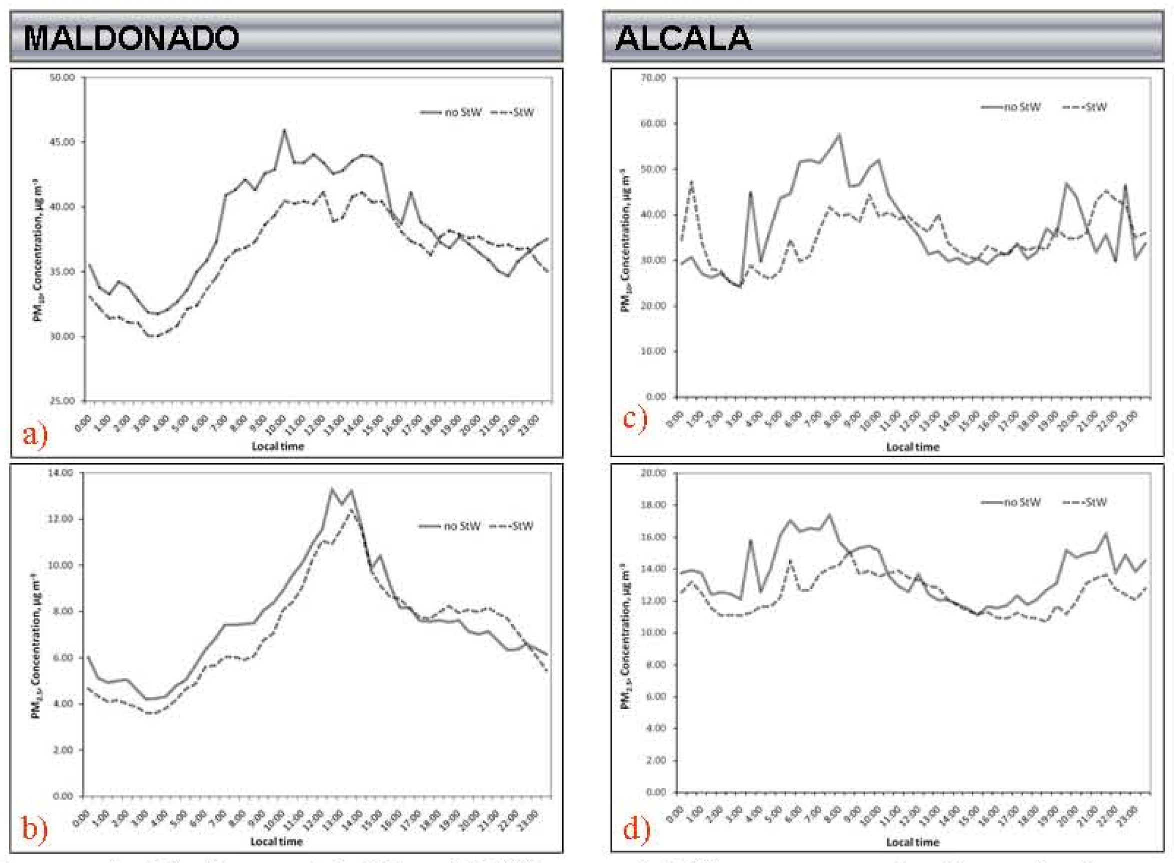

Figure 4. Daily variability of PM_{10} and $PM_{2.5}$ concentrations between StW days and no StW days for MALDONADO a) and b) and ALCALA sampling site c) and d).

The daily evolution of PM levels was evaluated in order to detect out any short term effect of street washing. Continuous measurements were separated into two subsets: 15 days with street washing and 16 days without street washing, Figure 4. For MALDONADO site a clear difference was established between these two periods for the early morning hours until early in the afternoon (00:00-16:00). However, this trend was not observed from 16:00 to 24:00 h. The mass difference between the two periods is ~4 $\mu g\ m^{-3}$ for PM_{10} fraction, and ~2 $\mu g\ m^{-3}$ for $PM_{2.5}$ fraction, about 10% of the measured mass concentrations.

For the second sampling site, ALCALA, the difference between the two periods was obvious from the early morning hours until 12:00, while this difference in terms of mass concentration was about 10 $\mu g\ m^{-3}$. In average the difference in the mass levels of PM_{10}, and $PM_{2.5}$ for the two periods was higher in this site about 25% of the measured concentrations.

PM_{10} Chemical components

PM_{10} daily samples were subjected to chemical analysis by the procedure described in Querol et al., 2001 in order to identify any differences in the hazardous components of ambient particulate matter when street washing is occurred in urban areas.

For Maldonado and Escuelas Aguirre sampling sites the difference between the sampling days with and without street washing was insignificant for the water soluble ions, Table 2.

Major metals like Ca, Al, K, Na and Mg that are emitted in the atmosphere during abrasion processes have showed a reduction during StW days. For trace elements like Pb, Sn, Zn and Ba, considered to be emitted from non-exhaust sources, a statistically significant difference of 10% was observed. For Alcala site the differences in mass concentrations were more pronounced. In this case, for these typical traffic tracers the reduction in mass concentrations for the days that street washing occurred was higher than 30%.

Table 2: Average concentrations of major and trace elements in daily PM_{10} samples

Average	MALDONADO		ALCALA		ESC.AGUIRRE	
$\mu g/m^3$	StW	no StW	StW	no StW	StW	no StW
OC	3.59	5.12	4.14	4.73	4.68	5.23
EC	3.95	7.64	5.48	6.72	3.99	5.18
NO_3	1.95	1.42	0.63	0.94	0.65	0.79
SO_4	1.79	1.80	0.86	1.18	1.11	1.13
Al	2.14	2.23	1.39	2.76	2.40	2.97
Ca	1.83	1.66	2.32	3.31	3.09	3.34
Fe	1.58	1.64	1.43	2.04	1.48	1.65
K	0.36	0.41	0.27	0.47	0.43	0.47
Na	0.45	0.47	0.37	0.71	0.46	0.54
Mg	0.28	0.29	0.22	0.37	0.27	0.29
ng/m^3	StW	no StW	StW	no StW	StW	no StW
Ti	64.73	60.79	41.82	63.57	53.93	58.52
V	2.33	2.03	1.63	2.33	1.77	1.97
Cr	12.28	12.96	8.80	15.62	8.46	9.77
Mn	22.00	22.90	19.29	30.47	20.99	23.87
Co	0.42	0.39	0.32	0.47	0.31	0.35
Ni	5.04	3.90	2.19	6.55	2.40	3.02
Cu	77.99	86.85	87.56	122.13	66.24	75.06
Zn	51.90	56.02	54.04	76.45	45.62	48.93
As	0.54	0.70	0.44	0.72	0.51	0.60
Se	0.30	0.25	0.20	0.27	0.24	0.31
Rb	1.76	2.10	1.57	2.44	2.45	2.64
Sr	7.74	6.47	5.88	8.94	10.43	7.45
Mo	24.93	24.59	13.10	46.61	22.80	24.27
Sn	17.09	18.02	15.81	21.74	12.48	14.60
Sb	12.42	12.89	12.75	17.25	9.44	10.78
Ba	48.48	52.66	46.94	64.95	44.10	43.85
La	0.64	0.58	0.34	0.56	0.86	0.59
Pb	6.36	9.40	6.53	12.10	5.22	8.41

Source Apportionment

Positive Matrix Factorization was used to interpret chemical composition PM_{10} data, so the contribution of different sources to suspended particles could be calculated. For this reason 24h PM_{10} data from the three sites (Maldonado, Alcala and Escuelas Aguirre) were combined. The best results were obtained when four factors were selected: vehicles emissions, secondary aerosol, road dust and soil. As it was expected vehicles emissions along with road dust were the major contributors in PM_{10} particle mass, Figure 5.

Then the daily variation of the source contribution was examined. The effect of street washing was evaluated by examining the daily variation of the road dust contribution between StW days and no StW days. The results revealed a reduction in the contribution of road dust, soil and vehicles emissions of about 25%, Table 3. On the other hand the secondary aerosol contribution had a different trend, during the StW days the contribution increased about 15%.

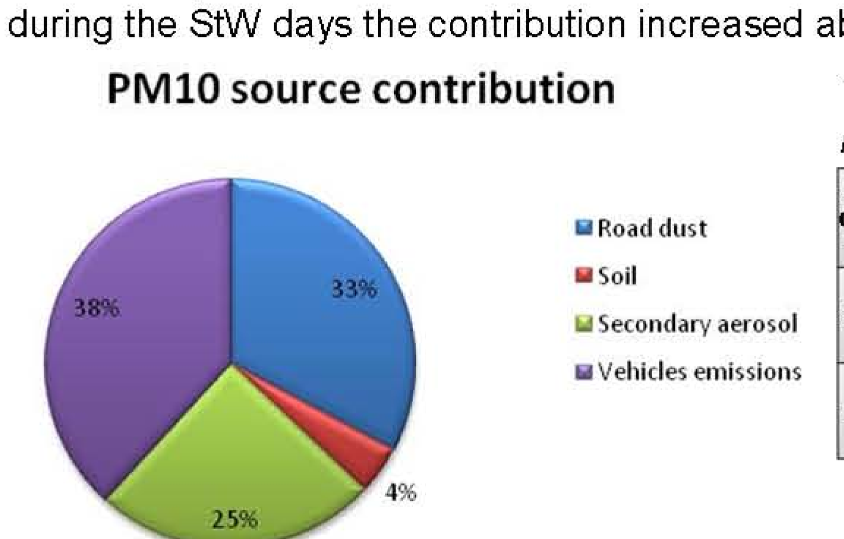

Figure 5. Source contribution (%) calculated by PMF for the urban area of Madrid

Table 3. Source contribution between StW days and no StW days

Average contribution $\mu g\ m^{-3}$	Road dust	Soil	Secondary aerosol	Vehicles emissions
StW	11.23	1.48	11.07	13.61
no StW	15.18	1.94	9.62	17.68

Though it merits further inquiry in future work, for the purpose of adopting strategies for the reduction of PM levels, we conclude that street washing has a positive effect. The results of the present study indicate that resuspension and street washing activities correlate positively.

Future work

The future work will incorporate the road dust chemical analysis results and the calculation of the emission factors

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